MARS CANNON ASSISTED FLYING EXPLORATION (CAFE). Jason. D. Denhart[1], Stormy. D. Faw[2], Justin. L. Petrilli[3], Sean. C. Webb[4], [1]North Carolina State University jddenhar@ncsu.edu, [2]North Carolina State University sdfaw@ncsu.edu, [3]North Carolina State University jlpetril@ncsu.edu, [4]North Carolina State University scwebb@ncsu.edu.

Introduction: A concept for Mars atmosphere and surface exploration was developed to deploy a compressed air cannon on the surface of mars that launches aerial exploration vehicles. The mission is envisioned for a 2026 launch window.

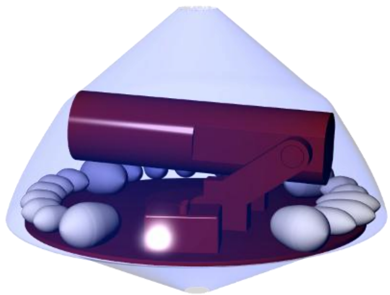

Figure 1: Packaged cannon and stowed aerial exploration vehicles

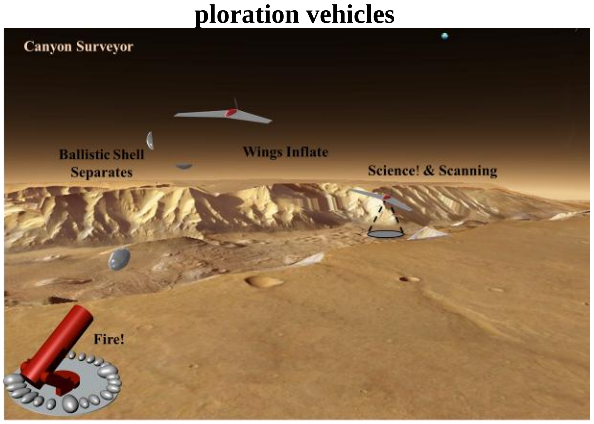

Figure 2: Illustrated system concept of operations

Scientific Goals: The site of primary interest is Valles Marineris. The landing site will be a crater at the head of the canyon. The aerial exploration vehicles will have a level flight range of 1,000 km which will allow them to explore the top half of Valles Marineris.

The primary scientific objectives come from the Mars Exploration Program Analysis Group (MEPAG) [1]. This concept is to perform the following investigations:

1. Goal II.A.4: Search for microclimates and study lower atmosphere climate processes.
2. Goal II.C.2: Find physical and chemical records of past climates
3. Goal III.A.1: Determine the formation and modification processes of the major geologic units and surface regolith as reflected in their primary and alteration mineralogies. [1]

The first of these goals can easily be addressed by *in situ* atmospheric measurements taken by an aerial vehicle. Canyons are a convenient place to study sedimentary stratigraphy because the rock layers are exposed for observation. These observations will provide information for both the second and third proposed science goals. The challenge is to deploy sensors in the canyon. Again, aerial explorers are well suited to this task. The cannon is used to overcome the significant challenges of flying in Mar's thin atmosphere by delivering the vehicles to flight speed and altitude. Thus the mass of the explorer is greatly reduced by leaving the means to affect take off on the ground.

Concept of Operations: The cannon shall land in a folded state in the aeroshell with the aerial vehicles stowed in ballistic shells around it. It will be powered by an Advanced Stirling Radioisotope Generator. A high pressure compressor will be used to exploit readily available CO_2 in the Martian atmosphere. The cannon has an articulating linkage that allows it to reposition itself to be charged by the compressor, loaded through the muzzle, and positioned to fire. The cannon will have a weather station and camera on board. A pressure tank surrounds the barrel to store energy until firing. It is separated from the barrel by a high-speed firing valve. The operation of the cannon starts with it unfolding and having the pressure chamber evacuated by the intake side of the compressor. It then moves so the ballistic shell of the first airplane is in its muzzle. The firing valve is opened, drawing the ballistic shell down to the bottom of the barrel and then reclosed. The pressure tank is then pressurized on the outlet side of the compressor to 2 MPa. Then it is pointed in the desired direction. The firing valve is opened to expel the ballistic shell. The cannon will have 150 W of electrical energy available. Its base load will be approximately 30 W with 120 W remaining to run the compressor and maneuver the cannon.

The shell containing the airplane flies ballistically until the velocity is sufficiently reduced that the airplane can be safely deployed. This occurs around 140 m/s and above 200 m altitude. At this point the ballistic shell opens like a rocket fairing and falls away from the plane. Two airplane architectures are used. The first is an inflatable flying wing. It has on board batteries that are charged by the ground station prior to launch and a CO_2 canister that is compressed by the ground station. Thrust comes for a large propeller that folds out from the sides of the airplane body. When the fairing opens, this plane rapidly inflates and powers up its propeller to begin its flying mission. The other architecture is more rigid. The wings fold back along side the fuselage and actuate to their flight position after the ballistic shell opens.

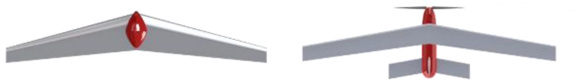

Figure 3: Inflatable and folding plane architectures

Four mission profiles are specified for these explorers. The first is that of atmospheric surveyor. This plane will have the inflatable architecture, and be optimized for high endurance flight (time). It will carry a suite of atmospheric sensors to measure pressure, temperature, wind-speed, and atmospheric chemical composition.

The second mission is that of canyon surveyor. This will also be of the inflatable architecture but will instead by optimized for maximum range (distance). It will carry a sensors to allow it to observe the canyon walls and bottom while in flight. Instrumentation will include cameras, spectrometers such as the M-TES and the and a Radar or Lidar rangefinder. Part of this vehicle's mission is to identify sites of interest for the remaining mission profiles.

The third mission is a canyon lander. This plane will be of the fold-out wing design and is optimized for payload transportation and to protect its payload in a landing. Its job is to deploy a Micro Lightweight Survivable Rover to the bottom of the canyon that would study the geography and geology of the canyon floor with instruments such as a rock abrasion tool (RAT), X-ray spectrometers and possibly a Ground Penetrating Radar (GPR.)

Finally, the fourth mission will be a cliff lander. This will be another inflatable type lander. It will be equipped with a microspine attachment system and retractable propeller that will allow it to perform a steep climb maneuver and attach to the side of a cliff when it reaches a low instantaneous speed. Once it is on the cliff, the flight systems will power down and the sensors similar to those on board the MLSR will deploy to study the geology and geography of the cliff wall. If flexible, high-strength solar arrays are developed in time for the launch window, the wings of the cliff lander would be made of solar panels that could regenerate its batteries so it can relaunch and fly to another site.

All of the vehicles will collect data during their mission. The data storage, communication antennae, and power systems willsurvive the end of their flight. When an orbital asset comes within range, they will upload their data to the orbiters for relay back to Earth. All flight will be fully autonomous. Scientists on Earth can command what chronology to fly the planes and can command flight directions and profiles before each launch. Navigation will be done autonomously, primarily by inertial schemes.

In total, 21 planes will comprise the mission. Table 1 shows the breakdown of the missions. A blanket mass growth estimate of 50% is applied.

Table 1: Mission breakdown and mass

System	**Qty.**	**Mass (kg)**
Ground Station	1	137
Atmospheric Surveyor	6	78
Canyon Surveyor	8	120
Canyon Lander	3	61
Cliff Lander	4	67
Subtotal	--	463
Mass Growth	50%	232
Total	**21**	**695**

The down mass of 695 kg can be landed at the appointed landing site in a manner similar to the Mars Science Laboratory entry descent and landing.

Analysis: Additional completed analysis on this mission include conceptual design and proof of feasibility into the subsystem level; power and mass budgets of all subsystems; detailed risk analysis and mitigation plans; mission, system, and subsystem requirements; and a list of technical challenges including paths to flight readiness of all in-the-pipeline technology.

Conclusion: This mission provides broad capacity for exploration of Mars and is particularly valuable in its potential to reach locations of scientific interest that are unavailable to traditional exploration vehicles.

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Reference:

[1] MEPAG (2010), Mars Scientific Goals, Objectives, Investigations, and Priorities: J.R. Johnson, ed., http://mepag.jpl.nasa.gov/reports/index.html.